SANITARY CONSIDERATIONS FOR CONTINGENCY OPERATIONS

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ABSTRACT

Military forces are frequently called upon to accomplish missions that involve temporary housing of military and civilian personnel for varying periods of time. This paper addresses the sanitary aspects of providing proper living conditions for military troops, temporarily displaced civilians and refugees. The primary focus is on the collection, storage, removal and treatment of human waste, and provisions for water and power supply to support these systems. Solutions are recommended from the aspect of Navy support for these operations, however, the general concepts are applicable to other branches of the armed forces, government relief agencies and other humanitarian relief groups. The emphasis is to provide simple, low complexity solutions to the handling of human waste. Installation must be able to be initiated quickly by a mix of unskilled workers, construction tradesmen, and contractor personnel. In many cases, the solution will include short-term and long term approaches to the problem that will work in tandem to cover the population requirements without service interruption.

SANITARY CONSIDERATIONS FOR CONTINGENCY OPERATIONS

A. INTRODUCTION

The immediate concerns of providing food, water and shelter often overshadow immediate and long-term environmental impacts during contingency operations. The problem of collecting and disposing of human waste can quickly become an overriding concern if not addressed at the initial stages of a relief operation. Uncontrolled defecation in crowded camps leads to high levels of diarrhoeal infection, cholera, and typhoid (Puddifoot, 1995). These health problems not only affect camp residents, but can also extend into surrounding local populations through contaminated underground and surface waters. Even deep wells can experience increased levels of nitrate contamination, which is especially harmful to infants, if adequate sanitation measures are not in place.

A contingency operation for the purposes of this paper is defined as a temporary support arrangement in which the armed forces, specifically the United States Navy and Marine Corps, are involved in the housing of persons displaced from their normal living environments by war or natural disasters. Recent examples include: Troop berthing during the Gulf War and subsequent sheltering of Kurdish refugees in that area; construction and operation of camps to shelter Haitian and Cuban refugees in Panama, Grand Turk and the U.S. Naval Station, Guantanamo Bay, Cuba; berthing of troops and refugees in Bosnia; and frequent hurricane, typhoon and earthquake disaster recovery operations in the U.S. and abroad.

U.S. military units that are especially suited for construction of contingency camps include the Army Corps of Engineers, Air Force Red Horse and Prime Beef units, Marine Corps Combat Engineer units, and the Navy Construction Force (Seabees). Current operations emphasize the use of all four services in joint operations to optimize the use of each unit's ability. The bulk of camp setup, however, does not require skilled construction forces to accomplish. Combat troops, engineers and refugees were all employed to establish basic camps in support operations for Cuban and Haitian refugees in Guantanamo Bay. They set up tents, cots, perimeter fencing, water supply and eating areas and temporary toilets that make up the basis of an expedient camp. Dedicated construction forces, however, later completed semi-permanent improvements including shower facilities, washing areas and flush toilets.

B. VARIABLES INVOLVED IN SUPPORT OF CONTINGENCY OPERATIONS

Selecting a method for meeting the sanitary needs of a population in such an operation is heavily dependent on local conditions. No single treatment approach may be appropriate in all situations. Therefore, it is extremely important to include engineers responsible for infrastructure construction in facilities planning from the outset. Where it is physically impossible for design personnel to visit the site in person, information should be collected from available sources and provided to them. This will reduce assumptions that could seriously interfere with appropriate handling and disposal of solid and liquid wastes. Important considerations are explained below:

1. <u>Size of population</u>: The nature of contingency operations is that of an interim

disruption to the normal day-to-day lives of the persons involved, and may result in a large concentration of people to support, such as a refugee camp, or may be more spread out geographically, such as in normal military security operations or natural disasters. Due to this variability, the size of the population and their living density are primary considerations in selecting a waste handling approach.

For small populations, from 10 to 100 persons, sanitation concerns are straightforward. In military units, troops will dig simple open pit latrines for human waste, covering the waste with a thin layer of dirt between uses to decrease odor and insect problems. This is normally appropriate for short-term use until the unit moves or builds more permanent facilities. Where space limitations or longer-term residence is expected, "Four-Hole Burnouts" can be construction of simple building materials for use by military personnel. Burnouts are wood latrine superstructures set up over drums of sand to receive waste. The drums are pulled out of the latrines daily and collected waste is burned using diesel fuel. Burnouts are not appropriate for normal relief efforts due to safety issues. Instead, the World Health Organization and other relief agencies have significant success in the building of pit latrines to support refugee camps in many countries (Howard, 1996). When properly constructed and maintained, these latrines can and have served populations of up to 100,000 refugees. An added advantage to this solution is that it is a technology that refugees in rural areas understand, trust and will use. It is also a technique that they can take back with them when they return to their homes to construct their own facilities.

Chemical toilets are a good short-term, sanitary solution where sufficient support equipment and

personnel are available. They are easy to set up, portable, and weather resistant. They can be set up in banks to support any size of camp population. Normally, one unit per twenty residents is used as a design basis (LANTDIV, 1994). These units require a high level of service to maintain their usability. Camp support personnel must pump out and clean the units daily in high use scenarios, with provisions made for subsequent treatment and/or disposal of the waste.

2. Length of Operation: The duration of a contingency operation is a difficult aspect to determine. For some situations such as natural disasters, the duration is a function of the level of damage to local homes and infrastructure. Relief agencies can often provide an accurate estimate of the time required for reconstruction. This information can help decide if short-term solutions such as chemical toilets will be acceptable. When political influences are present, however, such a determination of the time involved can be difficult or impossible. The political dimensions of refugee populations in Rwanda and Bosnia are recent examples of the need to provide facilities that may be used for years. Short-term solutions are useful only as interim measures until permanent or semi-permanent facilities are completed. Political decisions often limit the movement of refugees to alternate sites or return to their homes, making temporary facilities inadequate. Approaching this issue as a two or three phase process can address short term requirements until construction forces can build long term facilities or ship them to the site.

Construction of refugee facilities in Guantanamo Bay, Cuba reflected this approach. Military personnel augmented by refugees built expedient camps equipped with tents, 400 gallon water trailers and chemical toilets as refugees arrived. Construction just barely kept ahead of the arrival

of more refugees. At the same time, construction units were providing existing camps with water piping, concrete wash stations and concrete and wood enclosed showers in the order of initial arrival. This second tier of facilities was usually completed within four weeks of initial camp occupancy. Within approximately three months, new concrete block shower and toilet facilities were constructed and connected to a package waste treatment plant as a final, long term solution. These improvements were incidental to other camp improvements including chain-link fencing, strong-back tent platforms and overhead lighting. This proved to be an effective solution to a short-notice arrival of a very large population of displaced persons. Such an approach would be useful, although significantly more difficult, in dealing with mass migrations of refugees. An example was the fighting in Rwanda, where camp populations might exceed 100,000 in a very short time.

3. Sophistication of Residents/Cultural Issues: Populations being served in a contingency situation range from residents of industrialized countries who understand, prefer, and sometimes expect or insist upon flush toilets for use, to residents from rural or low-income urban areas who may or may not be familiar with pit latrines, much less flush toilets. During support of Bhutanese refugees in Nepal from 1992 to 1993, 87 percent of the 86,000 refugees reported they had never used a latrine, their only option being open defecation (Puddifoot, 1995). This situation is very common in rural areas of undeveloped countries. The level of understanding of the relationship between fecal contamination and health problems is also not always well understood. This makes it especially important to provide sanitation solutions that will encourage their use by providing privacy, simplicity and a relatively insect and odor free facility. Refugee support operations in

Guantanamo Bay, Cuba initially used prefabricated chemical toilets for the population of 30,000 Haitian and Cuban refugees (LANTDIV, 1994). While extremely effective as a short term solution, over time, they proved to be inadequate. Servicing and cleaning of these individual units quickly lead to mud and odor problems. Some camp residents stopped using the units and opted for open elimination with resulting odor and health problems. Bathing in these units compounded the problem until adequate shower facilities were completed. In camps where limited water supplies do not afford showers or private bathing areas, latrines are often used as bathing areas because they afford privacy. The resulting runoff can undermine foundations on pit latrines and cause subsidence collapse of the unit.

Another concern is that children will not use latrines for fear of falling into the pit, so construction of smaller seats and steps should be considered (Middleton, 1995).

4. Climate: Temperature and rainfall are important considerations. They will determine the need for ventilation, insulation, heating/cooling of toilet facilities, and appropriate design of more advanced waste collection and treatment systems. A system designed for warm weather tropical climates will not be appropriate for the harsh winters in higher latitudes. Biological degradation rates at different temperatures will influence the ease of handling solid and liquid waste as well as the amount of gas and odors produced. The climate will also significantly influence the complexity of insect control.

5. Soil Conditions/Topography: Soil conditions of concern include porosity, height of

water table, depth of confining strata, and soil type. Each will influence decisions on the suitability of installation of latrines, leach fields or piping for centralized treatment of waste. Although some information can be gathered by visiting a prospective site, information from local residents, especially from well drillers, can be extremely useful. Without such information, however, planners must make assumptions with alternate measures ready in case the assumptions fail. For example, if latrines are picked as the primary method of handling human waste, a layer of rock below the surface may make digging the pits impossible. This requires a shift to a more appropriate solution. Digging test pits before committing to such a course may be prudent.

The topography of a site reflects elevation and terrain influences. Large treatment facilities will require suitable flat sites for placement of required equipment, with smaller flat sites needed for siting latrines and shower facilities. An area of rugged or rocky terrain may make trenching difficult and prevent the use of a gravity collection system. Flat areas will require lift stations to allow gravity flow of waste, and may warrant the use of central collection manholes with a force-main to a waste treatment plant. Of equal consideration is an evaluation of the natural stormwater drainage for the area to avoid building in a flood plain or stormwater channel.

6. Environmental Standards of Quality: There is no one worldwide standard for the quality of wastewater effluent that is acceptable for discharge from a waste treatment plant or disposal unit, again making design of a single method of waste treatment acceptable worldwide very difficult. The safe approach is to design facilities that will meet the strictest discharge requirements, which normally means treatment to U.S. standards. The problem with this

approach is that for most developing countries, treatment to this standard will result in expending a considerable amount of scarce energy and material assets to reach an effluent quality that exceeds that of the bodies of water receiving treated wastewater. Unless a country already has an effective environmental program in place, overtreatment will have no influence on the overall water quality of the receiving body and be a waste of resources. If a facility is to be left in place for local use after the completion of a contingency situation, such a treatment process would be very unlikely to remain in use. Planners must tailor the treatment approach to the local standards with considerations made for future upgrades. For example, plant layout near a body of water should allow room for polishing ponds, clarifiers, etc. for future secondary or advanced treatment processes. A possible approach is to design treatment processes of modular construction to allow tailoring of primary and secondary treatment protocols as the situation requires.

7. Water Resources: The quantity, quality and source of water in the area are prime considerations when planning for a treatment process. The United Nations High Council on Refugees (UNHCR) standards for refugee camps call for a minimum quantity of 20 liters per person per day (Mulemba, et al., 1994) to meet the needs of drinking, cooking and washing. Relief efforts must provide this initial minimum requirement before considering any water-intensive waste collection and treatment processes. Water supplies should be assumed to be limited initially until wells, piping and water treatment processes can be put in place. Methods of extending water resources for flush-type systems include recycling of treatment plant effluent as flushing water, as well use of shower and wash station water ("gray water") as an augment to the flushing water supply. Salt water flushing systems may also be an effective solution, depending

on the ultimate treatment process. A related concern of centralized waste treatment where water supplies are limited is that the strength or concentration of the waste water will be high. This is an important design consideration for selecting treatment processes.

Waste treatment processes, whether by latrines or waste treatment plants, must be constructed such that they do not diminish the quality of existing water resources by introducing contaminants into the water supply. This concern will dictate the level of treatment required and the physical location of treatment plant outfalls. It may also prevent the use of latrines where the waste-treatment capacity of the soil is insufficient to prevent contamination of the underlying water table.

The source of water in the local area will affect the placement of camps. Waste treatment procedures must ensure that leachate, runoff or treatment plant discharges do not affect the source of water for the camp or for local residents. Camps should be established well clear of any existing water wells and the sites of any future wells to serve the camp. If planners know the groundwater hydraulic gradient, keeping the camp and waste treatment facilities down-gradient from water sources will reduce contamination risks. For water sources that are near the surface, standard pit latrines may not be appropriate. If used, they may require a waterproof liner to prevent infiltration of contaminants into the groundwater. While decreasing the usable life of the latrine, with proper construction, they will still have a service life of several years before pumping-out is required. Contaminants of concern include biological and chemical substances. While biological contaminants often have a limited migration distance before natural soil degradation

removes them from the system, nitrate contamination from ammonia can travel long distances and negatively affect local water sources with corresponding health concerns (Reed, 1994). Obviously, the density of the refugee population and resulting contaminant loading will determine the potential for groundwater problems where latrines are used. It will also be a key factor in the quantity of effluent from a waste treatment plant and the decision on physical location.

8. Infrastructure Availability: Infrastructure availability is critical to the planning and support process in a contingency situation. Sophisticated waste treatment scenarios may require transport by ships or barges, port facilities with crane support for offload and heavy vehicles for hauling components to their sites. Road conditions will also play a critical role in determining the feasibility of transporting components any distance inland. Air transport is expensive and limited to available airports and expedient runways, aircraft size, and relative priority of cargo. Package plants typically require a substantial amount of electricity to operate pumps and blowers which must be available onsite either in the form of an existing power distribution system or from portable generators brought to the site.

Another important aspect of infrastructure is the availability of sufficient common building materials such as lumber, concrete, piping and bulk mineral products. These materials play an important role in construction of latrine facilities, shoring and bedding material for trenches, piping networks for water distribution and waste collection, and maintenance of roadways. Military construction forces do not normally stock construction materials, relying on contract purchase of local material or off-site procurement and shipping instead.

C. CONSTRUCTION ASSETS

As noted in the introduction, the intent of this paper is to focus on the role of the Navy/Marine Corps team in addressing the problem of contingency sanitation, however, there are many other valuable assets available in both joint and single-service operations than can be used accelerate infrastructure construction.

1. U.S. Navy: The principle sources of construction assets in the Navy are the Naval Facilities Engineering Command (NAVFAC) and its Naval Construction Force (Seabees). NAVFAC can provide design support through in-house and contract assets as well as contract authority to procure and install components or entire systems for waste handling. Due to the unique skills required to run waste treatment processes, the ability of NAVFAC to contract for package plant waste treatment units including setup, operation and maintenance is an indispensable tool to be used for long-term treatment solutions on short notice.

The Naval Construction Force provides the ability to send a skilled, self supporting construction team into unstable areas at short notice. This is especially import in situations where it is not appropriate to send in civilian personnel. Their availability to commence construction efforts worldwide within 48 hours makes them a good selection for the initial stages of a disaster or refugee response until other assets including additional military and civilian personnel arrive. Their specific assets include carpenters, plumbers, surveyors, masons, welders, mechanics, equipment operators and engineers. They are able to build most of the facilities required to provide domestic waste treatment, but are not specifically trained in the operation and

maintenance of waste treatment systems. The Seabees have a limited water treatment capability, normally limited to a self-supporting capacity, but do have water-well drilling capabilities. The Naval Construction Force is limited to eight mobile construction battalions and two amphibious battalions on active duty, as well as a number of smaller units. Additional reserve assets are available to augment those numbers as conditions require.

Additional resources for construction within the Navy include civilian and military personnel assigned to shore facilities worldwide with the skills necessary to operate treatment facilities on an interim basis. For construction support, shipboard personnel are another possible asset as a source for skilled and unskilled labor.

2. U.S. Marine Corps: Marines are a ready source of skilled and unskilled labor at short notice and under any condition. Their Combat Engineer battalions possess significant construction skills, although their emphasis is toward battlefield construction activities. They also have reverse osmosis units for potable water production from salt and fresh water.

3. U.S. Air Force: Two Red Horse squadrons within the Air Force provide a mobile, short notice construction asset similar to the Navy's Mobile Construction battalions, although on a smaller scale. Their Prime Beef units provide base support capabilities and may have sufficient trained personnel available for water and wastewater treatment plant operation. They also have the equipment and personnel required to support chemical toilet pumping operations where used. Another capability lies in their Prime Power units to provide large scale electrical power

generation, a possible requirement depending on the power needed for most package treatment plants.

4. U.S. Army: The Army has a variety of useful assets available for large scale operations, specifically heavy construction equipment for earthmoving operations, power generation and portable, high capacity reverse-osmosis plants and expedient pumping/piping systems. Their smaller scale construction assets are limited. They also have water well drilling capability.

5. Local Assets: Local construction companies and construction material suppliers can prove an invaluable asset in meeting construction needs. In addition, their use promotes a sense of community involvement and benefit from the construction of the required facilities. They not only augment the construction effort, but are also important sources of local soil and climate conditions. They may also assist in tailoring standard construction techniques to meet local conditions.

6. Refugees: Refugees represent a tremendous source of skilled and unskilled labor to aid in the construction and maintenance of waste handling facilities. With supervision, they are normally solely responsible for constructing and servicing latrines in camps run by the UNHCR. In Guantanamo Bay, Cuba and in Haiti, camp residents volunteered extensively to help construct camps and infrastructure. Their employment has the added benefit of occupying their time with productive work and allowing them to provide a level of self-support.

D. SELECTION OF TREATMENT PROCESS

The expedient nature of contingency operation does not always allow for collection of detailed information on a site before refugees begin to arrive. Planners must make decisions with the best information available at the time, with provisions made for later improvements as time and resources allow. At the earliest opportunity, an evaluation of the site with sanitary considerations in mind should be made to aid planning and design personnel with as much information as is possible. Appendix A provides a systematic method for gathering information of this nature which can be completed by onsite personnel or by engineers on a dedicated site visit.

Treatment approaches can be broken into two general categories depending on the availability of fresh treated water: "dry" or non-flushed systems and "wet" or flushed systems. Each category can then be broken down further to tailor treatment to the local conditions.

1. Dry Systems: Dry systems are necessary in arid areas or where refugee populations are so large that available potable water resources are sufficient for drinking and food preparation only. They may also be the most practical solution if material and labor required to install and operate a flushing and treatment system are not available, or as an interim measure until such systems are completed. Examples of dry systems include simple pit latrines, Ventilated Improved Double-pit (VIP) latrines, and the military 4-Hole Burnout/Urine Soakage Pit combination. These systems involve simple construction that can be accomplished by properly supervised unskilled workers.

a. Pit/VIP Latrines: Pit latrines provide a quick, flexible, long term solution to human waste disposal. The units require very little maintenance or upkeep and are easy to backfill or remove once an operation is complete. Disadvantages include: potential for odor problems, reduction of groundwater quality from closely spaces pits and acceptance by the population being served.

A variety of styles are in use today throughout the world. Relief agencies may be able to provide information as to the normal technique used by the expected camp populations. Planners should consider adopting that method or similar technique to ease their transition into the camps. Figure 1 shows a Ventilated Improved Double-pit (VIP) latrine widely used by the World Health Organization in rural areas and in some refugee camps. It is a simple pit latrine, suitable for most soils. In areas where the water table used for drinking water is near the surface, builders may have to line the pit with an infiltration barrier such as brick or concrete to avoid groundwater contamination. Such a situation significantly increases the construction effort and will make alternate approaches much more attractive. Figure 2 provides details for construction of an Offset Pour-flush Latrine that works to reduce insect and odor problems with a water seal in the bowl. It is especially useful for cultures that wash themselves after use of the latrine since wash water acts as flushing/seal water as well. Water volumes involved for this practice are small, so overfilling of the waste pit with liquids in excess of the infiltration capacity of the soil is normally not a problem. For high water table areas. pit levels should be monitored initially to ensure this does not become a problem. Simple pit latrines are also commonly used despite their susceptibility to odor and insect problems. Their ease of construction and simple technology make them a quick, reliable solution.

Figure 1. Ventilated Improved Double-pit (VIP) Latrine (Adapted from Middleton, 1995).

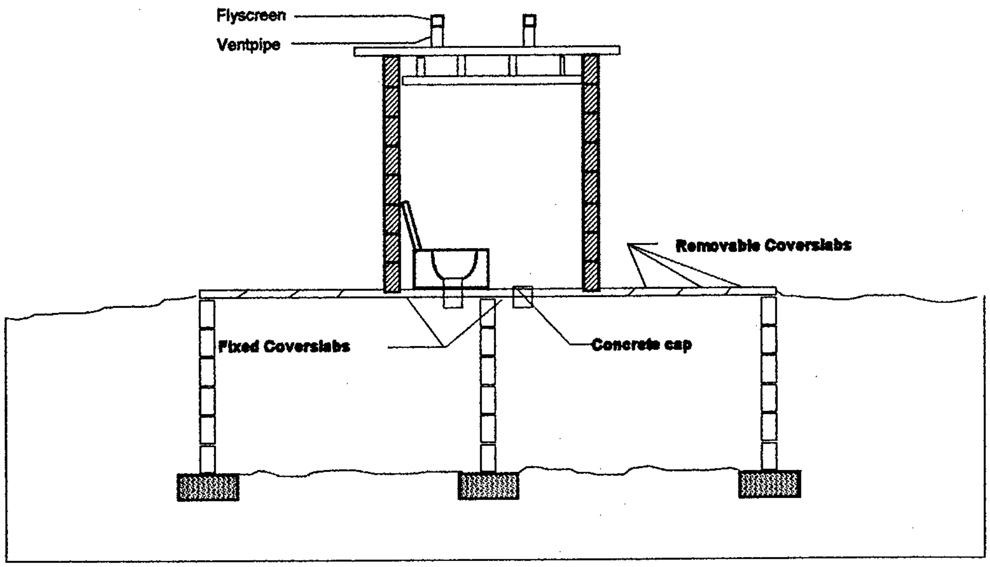
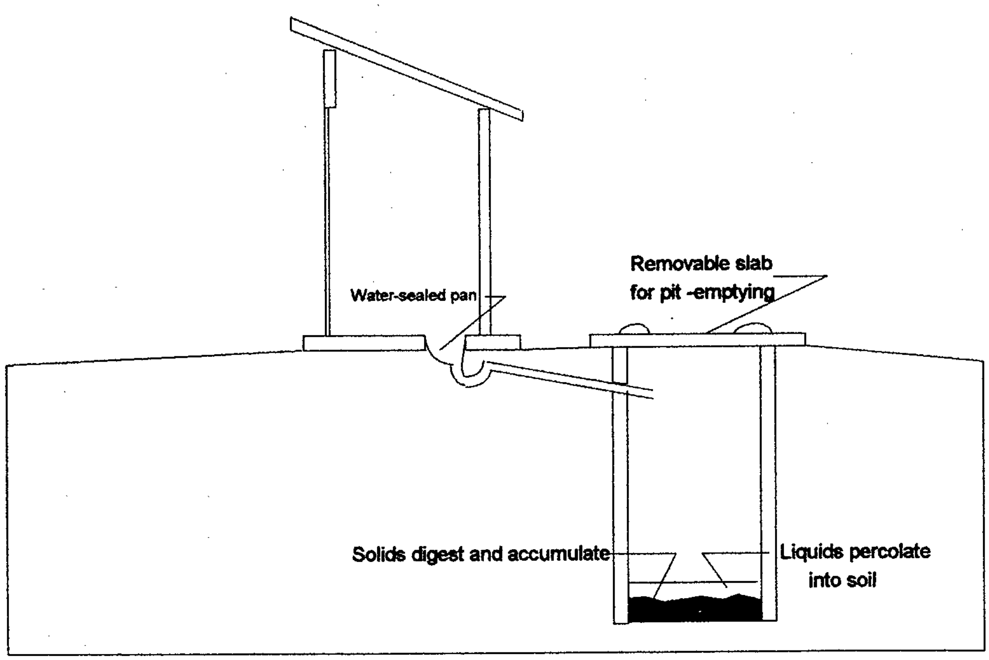


Figure 2. Offset Pour-flush Latrine (Adapted from Reed, 1994).



b. 4-Hole Burnout/Urine Soakage Pit: U.S. Navy and Marine Corps personnel involved in long duration contingency operations normally use burnout latrines for disposing of human waste. In these units, a wood latrine superstructure is built, with a section of 55-gallon drum partially filled with sand placed under each toilet seat. Camp support personnel pull the drum sections out of the wood structures daily for cleaning. Cleaning is accomplished by pouring diesel fuel into the drum half and burning the waste. After the fuel and waste are consumed, the drum is placed back into the burnout for reuse. The advantage of this system is simplicity, sanitation and vector control. This process can be used indefinitely. The disadvantage is daily maintenance and a limited amount of air pollution produced in the burning process. A ready supply of fuel is also needed, which may be a problem in remote areas. Seabees used this approach successfully during operations conducted in Somalia and Grand Turk.

Burnouts are appropriate measures when used by disciplined troops, however, they are not appropriate for large, densely populated refugee camps due to the smoke produced. The fire risk makes them marginal to unacceptable solutions for refugees, especially when children are involved.

c. Chemical Toilets: The use of chemical toilets may also fall into the "dry" category, although cleaning, disinfection and refilling of toilets and pumper trucks as well as some ultimate disposal techniques consume a large amount of water. Planners must consider this when selecting this option. They may produce a less offensive odor when kept clean and emptied often, but cleaning efforts can lead to collection of mud and contaminants in the immediate area of the facilities. Since commercial prefabricated toilets do not have floor drains, waste water from

cleaning the interior of the units washes out onto the ground. This increases the risk of spreading diseases such as typhus, cholera, salmonella, hepatitis and parasitic worms (LANTDIV, 1994). Cleaning and emptying the units is very labor and equipment intensive and requires extensive training to be conducted safely. This option is a very good short-term, interim solution until construction forces complete other facilities.

2. Wet Systems: Wet systems use flushing water to transport and dilute waste for further treatment away from the immediate area, either to an individual treatment unit for a specific camp, or to a centralized treatment plant that handles waste for several camps. Wet systems provide an odor-free, sanitary environment for the user when operated and maintained properly. They are, however, more expensive to construct and operate, take longer to put in place, and must be constructed in such a way as to prevent removal and pilfering of fixtures.

Wet systems require a much more complicated treatment and disposal process than dry systems due to the increased volume of waste created by use of flushing water. They can collect and treat shower, laundry and food preparation drains that cannot be treated by dry systems. There are many treatment options available, depending on local environmental conditions, water and power availability, crane and transportation assets and the required timetable to commence operations. Of primary importance, however, is the selection of the personnel to operate the selected treatment facility. Operating personnel can be grouped into three categories: military engineer forces, local workers and trained contract employees.

a. Operation by Military Engineer Forces: Military members are not normally trained in

the operation of sophisticated waste treatment plants and are not assigned duties requiring such training. They do have the requisite skills, however, to construct and maintain simpler plants that do not require constant monitoring to operate. Examples of these types of plants would be large septic and Imhoff tanks, trickling filters, slow sand filtration, treatment lagoons and similar slow-rate treatment processes. Testing of influent and effluent streams would require specific training that would conveniently fall within the skill level of assigned engineering aide or medical personnel. This paper will focus on these low rate treatment processes.

b. Operation by Local Workers: For situations in which a waste treatment system will be left in place and turned over to the local government for continued use, it is still appropriate to select a fairly simple treatment process. It is commonly difficult to keep highly trained personnel in remote areas (EPA, 1992). Trained operators of advanced systems tend to migrate to larger urban areas where wages are higher for their skill level. Simpler systems will also increase the likelihood that the system will remain in use after the contingency operation is concluded if the system is reliable and relatively maintenance free.

c. Operation by Trained Contractor Employees: Use of high-rate treatment processes normally found in small package plants requires specific training to keep systems in balance and ensure adequate treatment. In situations where contracted package plants are to be used, companies normally offer the option of using their personnel to operate the plant for an additional fee. Given the complex nature of these waste treatment processes, as well as the extensive training required for even a short duration contingency situation, it is prudent to select the option of contractor provide/operate when using package plant systems. An alternative option would be

to require a contractor technical representative to accompany the unit and train local or military personnel on the operation for an extended period of time, possibly for the duration of the contingency.

Table 1 provides a summary of the advantages and disadvantages of dry and wet treatment processes.

Table 1. Comparison of dry and wet waste treatment approaches.

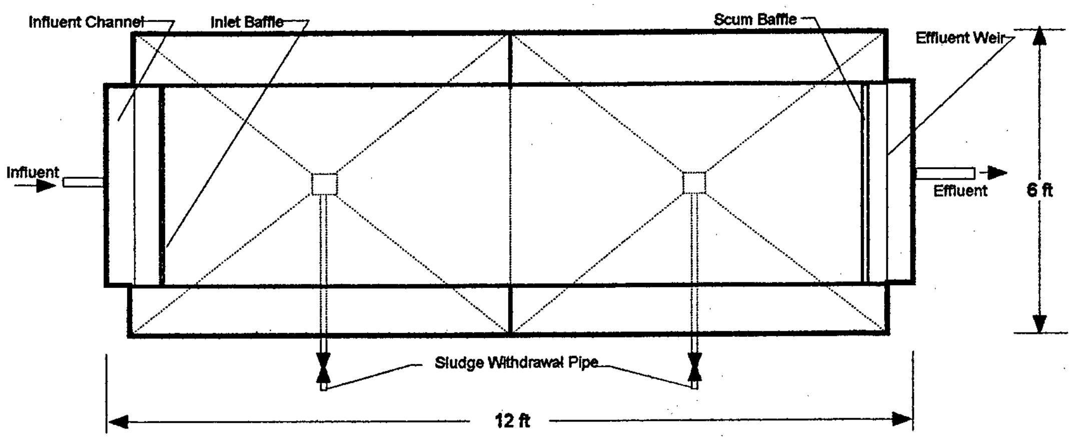
Treatment Process	Treatment Approach	Advantages	Disadvantages
DRY	Pit Latrine	Low Cost Rapid installation Simple construction Long life	Odors Potential groundwater contamination Septage disposal
	VIP Latrine	Same, with longer useful life	Same
	4-Hole Burnout	Low Cost Sanitary Rapid installation	Air pollution potential Fuel requirement Safety
	Chemical Toilets	Low Cost Simple set-up Pre-fabricated Sanitary	Daily clean/pump-out Waste disposal Equipment intensive
WET	Standard flush systems	Sanitary Wide acceptance Meets discharge standards	High water usage Treatment plant req'd Long construction time Pilferage potential Operating personnel Sludge disposal High cost
	Flushing with WTP effluent	10-25% less water	Higher disinfection rqts Separate pump/piping system required Potential for cross-connect

E. PRIMARY TREATMENT PROCESSES

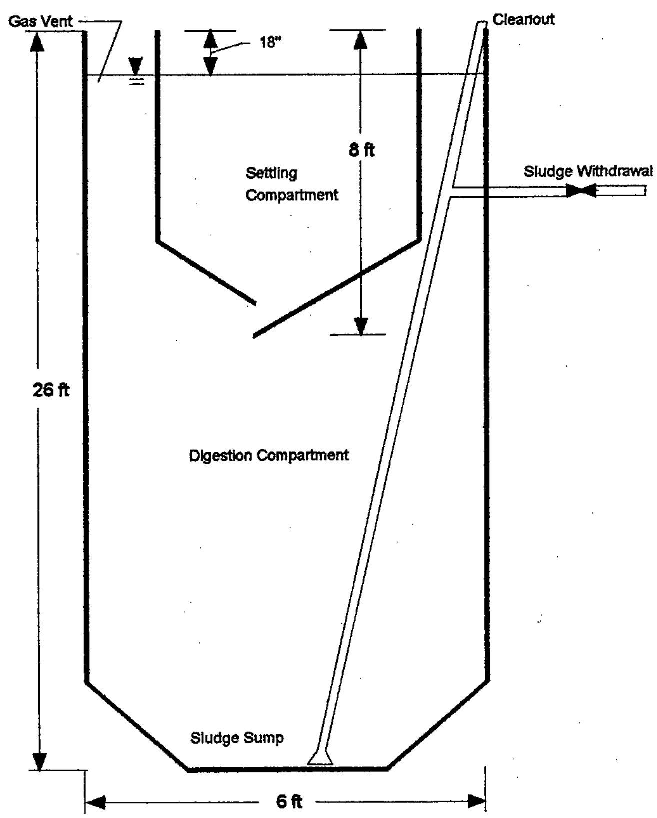
Primary treatment processes remove the bulk of suspended solid matter from wastewater, normally through settling under quiescent conditions. Conventional centralized waste treatment plants utilize large circular or rectangular concrete clarifiers to accomplish this settlement. This approach requires a significant construction effort that is not appropriate in a contingency operation. A more appropriate approach specifically adapted to serve small communities is the use of an Imhoff tank (Figure 3) shown on the next page. The tank shown is designed to accommodate the expected waste loading from a typical 500 man camp and provide sludge digestion and storage for six months before sludge withdrawal is required (design calculations provided in Appendix B). A steel tank of this size is small enough to allow air shipment. It may be loaded and transported with existing forklift and trucking assets found in a construction unit. Due to the corrosive effects of anaerobic sludge digestion that will occur in the tank, an appropriate protective coating must be applied during fabrication. Installers should locate the tanks downwind from camps to prevent odors from reaching living areas.

An alternate primary treatment method to be considered is the construction of sewage lagoons. Although they take up a large land area and require significant earthwork, little raw material or logistical support is required in their construction and operation. For a typical 500 man camp, two 8 foot deep ponds roughly 100 foot square would be required for anaerobic, low rate primary treatment (Metcalf & Eddy, 1991). Secondary treatment of the effluent from these ponds would be required.

Figure 3. Imhoff Tank for a 500 man camp (Adapted from Metcalf & Eddy, 1991).



Plan View (not to scale)



Section View (not to scale)

F. CENTRALIZED SECONDARY TREATMENT PROCESSES

Secondary treatment processes are designed to bring wastewater quality up to a level to allow discharge either directly to waterways or through a final polishing step before discharge. The major emphasis is to significantly lower the biochemical oxygen demand (BOD) of the wastewater through physical or biological treatment. The centralized approach requires an area sewer system with gravity flow, pressure mains or a combination of both to collect waste and deliver it to a common treatment plant. Package plants can be tailored to handle a range of waste flow rates by adding reaction chambers in series or parallel to increase capacity. Some examples are:

1. Extended Aeration: Extended aeration plants do not normally employ primary clarification in the treatment process. They rely on high aeration rates to maintain particles in suspension until the wastewater reaches the secondary settling tank for particle removal. Waste sludge is returned to the head of the aeration tank for recycle, while clarified effluent leaves the plant via a chlorine contact chamber for final disposal.

2. Contact Stabilization: Contact stabilization reduces the aeration volume requirements by half as compared to equivalent extended aeration tanks. Two separate compartments are used for the treatment of wastewater and stabilization of activated sludge. Systems can be designed to treat either settled or raw wastewater.

3. Sequencing Batch Reactors: The sequencing batch reactor is a fill-and-draw system using a series of complete-mix tanks or lagoons for treatment. Since the required reactor tanks are too large for prefabrication, extensive construction effort is required to build them onsite. This would be a good option for a treatment facility that will be left in place for use by the local residents once a contingency operation is concluded, but will require a long lead time to construct.

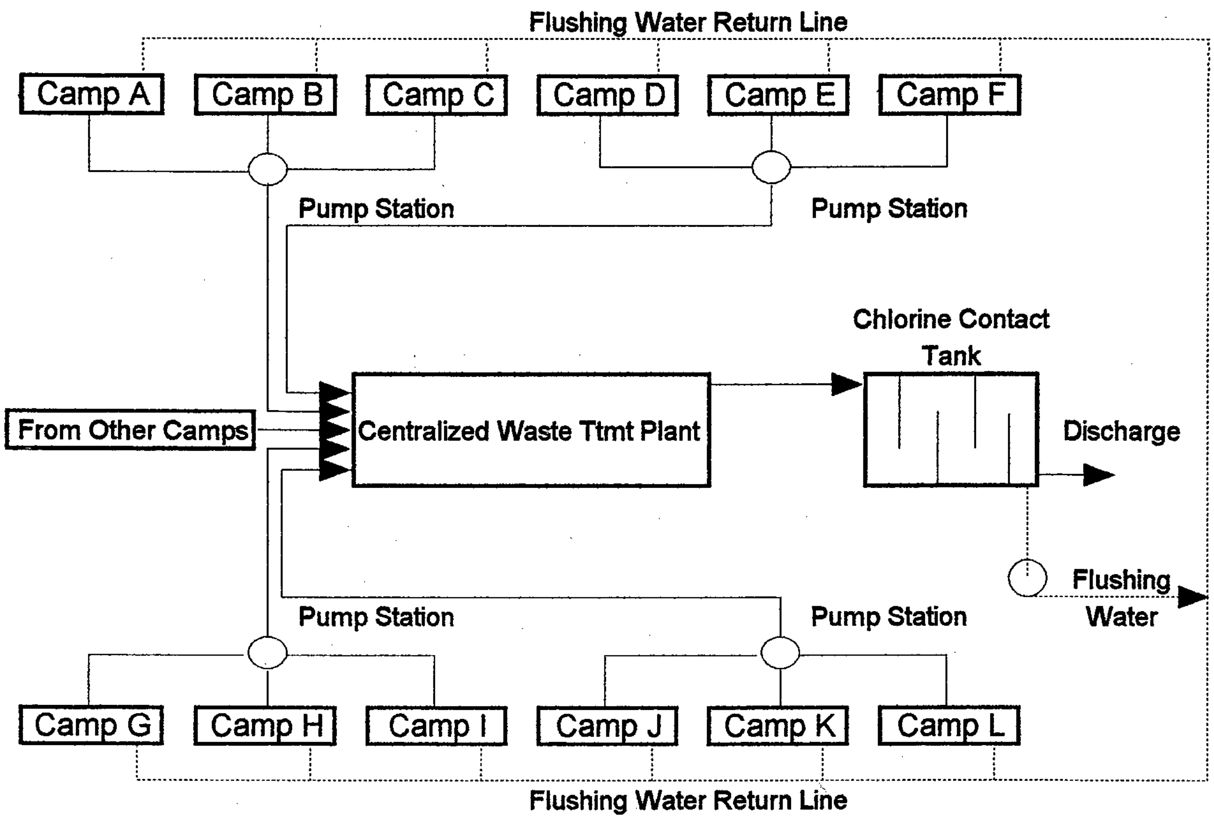
4. Rotating Biological Contactor: Rotating biological contactors employ a rotating disc with an attached biofilm to treat wastewater. Primary settlement is required to avoid solids buildup on the discs. Due to their compact size and ease of series or parallel operation, they make a convenient transportable treatment unit.

5. Physical/Chemical Treatment: This treatment approach is expensive and produces a large volume of sludge, so it is not widely used. Since it does not employ biological processes, however, it is an effective treatment in cold climates and for intermittent, on-off waste treatment. A typical system employs chemical treatment to improve settling, a sludge blanket system for initial clarification, followed by filtration and carbon adsorption.

In general, a centralized approach to wastewater treatment is appropriate where water resources are sufficient to support a wet system of waste collection and transport, camps are within a reasonable distance to allow pumping from the user site to a central treatment site, and large populations (over 5000) are expected. Figure 4 represents a typical centralized facility with a

portion of treated effluent reused for flushing water. A similar system was used successfully to support refugee camps from 1994 - 1995 at Guantanamo Bay, Cuba.

Figure 4. Typical plant layout for a centralized wastewater treatment system.



G. DECENTRALIZED SECONDARY TREATMENT PROCESSES

Decentralized systems have the same treatment goals as centralized systems but are normally characterized by their low energy treatment approach. They are small units that are normally located in close proximity to the waste source and have an overall greater land usage requirement than centralized systems. Primary treatment for small communities is commonly provided by septic tanks or Imhoff tanks. Pumping and piping costs are minimized by their close proximity. Some examples are:

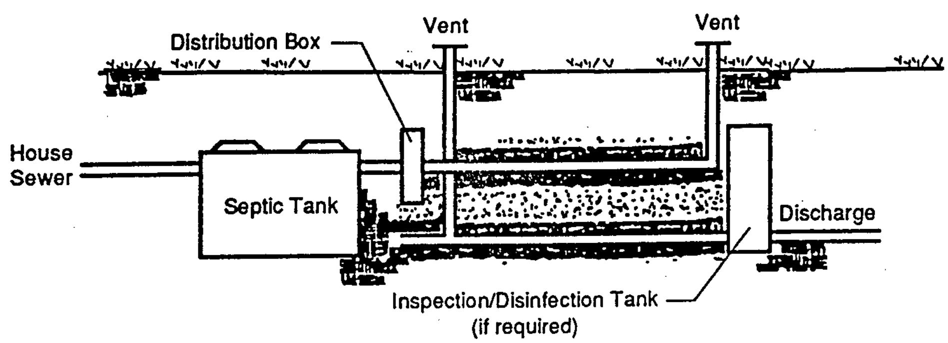
1. Slow Sand Filters: Slow sand filters are used for small communities. They consist of one or more sand filter beds that may be covered or exposed to the surface. Primary treated waste is intermittently applied to the sand filter media and allowed to pass under aerobic conditions and undergo biological treatment. Treated filtrate is collected by an underdrain system for recycling or disposal. Table 2 outlines basic design parameters:

Table 2. Design Criteria-Slow Sand Filters (EPA, 1992).

Design Factor	Buried	Open	Recirculating
Pretreatment	——Minimum of Sedimentation——		
Media specifications			
Effective size (mm)	0.7–1.00	0.40–1.00	1.0–1.50
Uniformity coefficient	<4.0	<4.0	<4.0
Depth (m)	0.60–0.90	0.60–0.90	0.60–0.90
Hydraulic loading (cm/d)	4–6	5–10	12–20 (forward flow)
Dosing frequency	2–4/d	1–4/d	5–10 min/ 30 min
Recirculation ratio	NA	NA	3:1–5:1

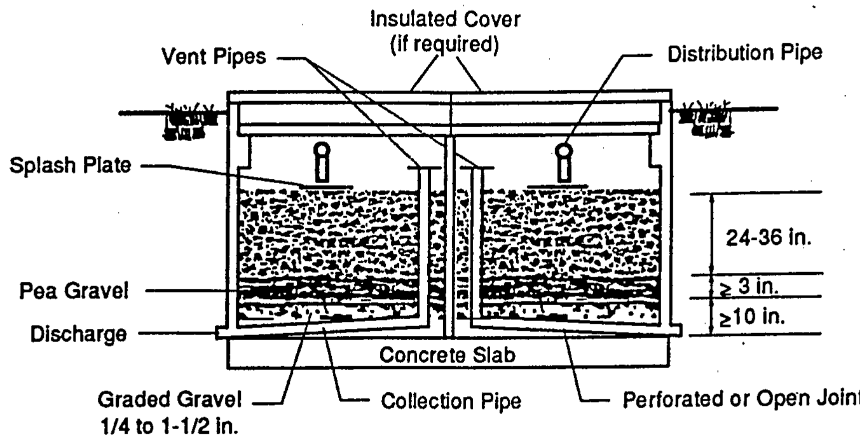
a. Buried Sand Filters: These single-pass sand filters are typically built below grade and lined with an impermeable synthetic material. Filtrate is collected by an underdrain system for final discharge. Distribution and discharge piping is vented to maintain aerobic conditions in the sand medium. Solids removal is not required, but the small loading rate of one gallon per day per square foot of filter area results in large filters. They are normally associated with single residence treatment and discharge to a leach field.

Figure 5. Buried (Single Pass) Sand Filter, (EPA, 1992).



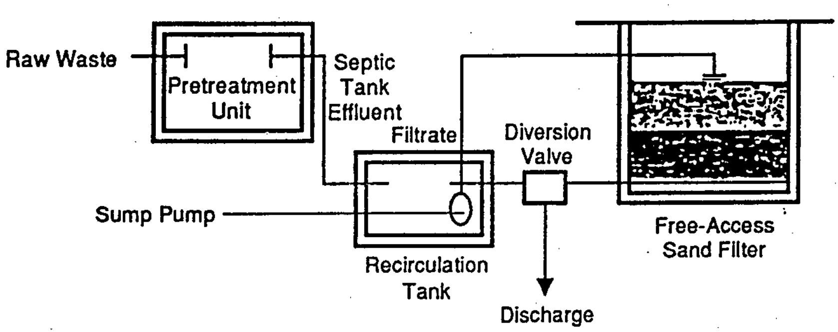
b. Open or Intermittent Sand Filters: Open sand filters have a larger treatment capacity per square foot of surface area than buried filters. The filter is exposed to the surface to allow inspection and periodic replacement or cleaning of the sand media. Removable covers can also be installed if required to prevent freezing or to shed excessive rainfall. They operate on a single-pass treatment process.

Figure 6. Open or Intermittent Sand Filter (EPA, 1992).



c. Recirculating Sand Filter: Recirculating sand filters are open sand filters equipped with a recirculation tank to mix incoming wastewater with a portion of the treated filtrate. A timed submersible pump provides regular dosing to the filter.

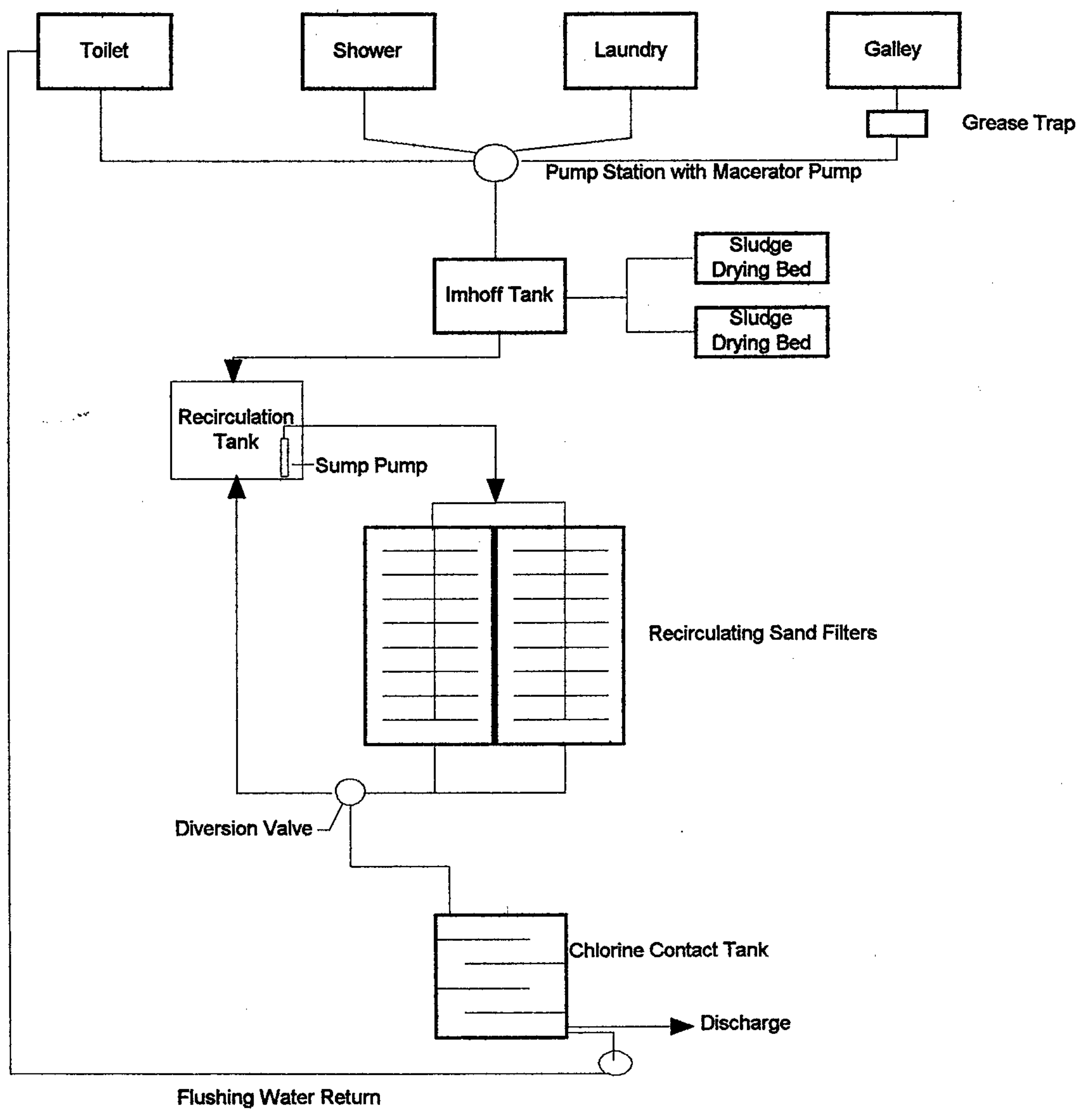
Figure 7. Recirculating Sand Filter (EPA, 1992).



Sand filters treat wastewater through a combination of biological and physical processes. The filters act as a fixed film biological reactor to typically produce effluent five-day biochemical oxygen demand (BOD_5) and suspended solids concentrations of 10 mg/l (EPA, 1992). This is well within U. S. discharge requirements. Successful removal of nitrogen, phosphorous, viruses

and fecal coliforms are also reported to be very high. Figure 8 reflects a typical plant layout for a decentralized system.

Figure 8. Typical plant layout for a decentralized wastewater treatment system.



H. FINAL EFFLUENT TREATMENT

Water quality after secondary treatment will normally meet the discharge standards required for municipal wastewaters without further treatment. Tertiary treatment through the use of activated carbon or rapid sand filtration may be required in isolated cases where either standards are extremely stringent or the waste treatment process selected does not consistently meet required discharge quality. Each of these processes can be added on to the waste treatment process without affecting the upstream treatment. Rapid sand filters will require a clearwell of treated effluent to accomplish periodic backwash, with backwash flow being directed to the head of the treatment plant to mix with incoming wastewater. They will normally remove fifty percent of the dissolved and suspended contaminants remaining after secondary treatment (Metcalf & Eddy, 1991). Activated carbon units adsorb up to ninety five percent of dissolved materials, but must normally be preceded by a filter to prevent clogging. Each process results in a significant increase in effluent quality.

Disinfection is required prior to discharge into open waters, although not required for land disposal through leach fields, infiltration basins or irrigation of vegetation not meant for human consumption (i.e. pastureland). Disinfection for contingency operations will normally be limited to chlorination. Ozonation units may also be used, however their electrical demand is very high. Chlorination is normally accomplished by mixing compressed chlorine gas with the wastewater stream and allowing for twenty to thirty minutes of contact time prior to discharge. Liquid and solid forms of chlorine are also available and may enhance the safety of the field operation.

Upon completion of disinfection, treated wastewater is available for recycle as flushing water, discharge to open waters, or reuse by the local community for agricultural purposes. Reuse in arid areas is especially important to extend limited water resources. UNHCR and World Health Organization representatives should be consulted to determine the most effective disposal approach for a particular community that takes into account both agricultural needs and cultural concerns.

I. SLUDGE TREATMENT AND DISPOSAL

Sludge is produced by many of the treatment processes described so far, and may be a driving factor in choosing a treatment process. Sludge from primary treatment contains approximately four to six percent solids by weight, and is present in a liquid form. Sludge from secondary biological processes found in most package plants contains from one to four percent solids. Sludge at twenty percent solids or higher is dry enough to load into trucks and dispose of at most landfills. Few landfills will accept liquid sludge. Land application of liquid or solid sludge is another disposal option provided steps are included to stabilize the sludge prior to application

1. Dewatering: Sludge dewatering is required prior to sludge disposal in landfills or land application with manure spreaders. Drying beds are used due to their simple technology and low labor requirement. For low sludge volumes expected in contingency operations, drying beds should not impose a critical space requirement. Table 3 lists area requirements for drying beds based on a per-capita and a sludge volume basis.

Table 3. Typical Area Requirements for Open Sludge Drying Beds (Metcalf & Eddy, 1991).

Type of sludge	Area, ft^2/person[a]	Sludge-loading rate, lb dry solids/$ft^2 \cdot yr$
Primary digested	1.0–1.5	25–30
Primary and trickling-filter humus digested	1.25–1.75	18–25
Primary and waste activated digested	1.75–2.50	12–20
Primary and chemically precipitated digested	2.0–2.5	20–33

[a] Corresponding area requirements for covered beds vary from about 70 to 75 percent of those for the open beds.

Sand drying beds are constructed of successive layers of sand and gravel with an underdrain system to remove underflow water. Underflow is returned to the primary process for treatment. Temporary covers may be erected on rainy days to decrease rainfall effects on the drying process. Once the sludge is dry, it can be shoveled into trucks for disposal. For centralized treatment plants, this will be a continual process. For decentralized plants using septic tanks or Imhoff tanks, sludge handling will occur every three to six months.

2. Land Application: Land application of liquid or solid sludge is a common technique in rural areas and may lend itself well to use in contingencies in remote areas. Liquid sludge can be spray applied to a dedicated land application area using sprayer trucks or sprinkler systems. Solid sludge can be spread with a manure spreader. It is a simple process that also provides substantial benefit to agricultural or marginal lands by acting as a soil conditioner and source of organic matter and nutrients.

Land application requires sludge that has been stabilized to kill pathogens and decrease the

amount of biodegradable solids for odor reduction. Stabilization in contingency situations should focus on techniques that limit storage time to avoid requirements to build large storage tanks or aerated lagoons. Air drying on dewatering beds as previously discussed meets the stabilization requirements for land application. For liquid sludge, sufficient lime added to the sludge to raise the pH above 12 for 30 minutes will also stabilize the sludge and for land application without further dewatering or treatment (EPA, 1992). Selection of treatment and disposal approaches will depend on site availability for land disposal or landfilling and the logistics of delivery of lime for stabilization. Land application may also have a political benefit by supporting local agriculture in the area of refugee camps.

J. CONCLUSIONS AND RECOMMENDATIONS

Contingency operations expend vast amounts of resources upon short notice. Time, supplies, equipment and manpower are all valuable resources that must be conserved by making the best use of them. For this reason, planners must quickly decide on a treatment process or phased series of processes. Planned steps must not only provide immediate relief for displaced persons, but also minimize the resource drains of maintaining and operating waste disposal systems. Appendix E contains a decision flow chart to aid planners in selecting an appropriate treatment method. The flow chart emphasizes use of simpler treatment processes for short term operations, for initial phases of a contingency until semi-permanent facilities are available, or in situations where water resources are insufficient to provide flushed systems. Existing waste treatment

facilities should be used where present, even if it requires funding plant upgrades to support increased loading rates.

Chemical toilets are listed as a primary method of interim waste handling. For scenarios in which treatment facilities are not available to treat septage pumped from the toilet tanks, an Imhoff tank can be used with a sand filter for interim treatment until other flushed systems are completed, or as a long-term treatment solution if chemical toilets will be used for a long period of time. Since Imhoff tanks and slow sand filters are a flexible, low cost and low complexity treatment option, several tanks should be constructed and stored for immediate use. Specific recommendations are as follows:

> Recommendation 1: Assign the Navy Civil Engineering Laboratory or the Naval Facilities Engineering Service Center responsibility for design of a steel or aluminum Imhoff tank suitable for air transport in a C-130 aircraft using Appendix B as the design basis. Emphasis should be on stability when erected coupled with minimum outside dimensions and weight. A prototype should be built and tested to ensure proper operation prior to contracting for additional tanks.

> Recommendation 2: Assign Construction Battalion Center, Gulfport, MS responsibility for procurement of six tanks for contingency operations. Four should be placed in storage: two at Construction Battalion Center, Port Hueneme, CA, and two at Construction Battalion Center, Gulfport, MS. The remaining two tanks should be

assigned to the Naval Construction Training Centers for hands-on training as part of Utilitiesman "C" School.

Recommendation 3: Assign Chief of Naval Education and Training responsibility for developing appropriate training curricula for operation of Imhoff tanks and sand filters.

Recommendation 4: Assign Naval Facilities Engineering Command responsibility for design of construction assemblies or kits for construction of recirculating sand filters, prefabricated chemical toilets, sewage lift stations, flush toilet latrines and pressure sewage systems. Procure sewage pump trucks for chemical toilet servicing. Stock kits and vehicles in Strategic War Reserve for contingency use.

Recommendation 5: Naval Facilities Engineering Command develop guide specifications for contracting of package waste treatment plants. Contracts should require the successful bidder to deliver, set-up and operate the plants where possible. The bid price should include purchase of utilities from the government or local utility at the prevailing rate in that area. Alternative guide specifications should address scenarios that provide leased units with technical representative support and for leased units with factory training of military personnel to act as operators. Purchase of units should be avoided unless the units are to remain in place after the contingency operation is complete. NAVFAC should also maintain a selected bidders list for this type of contract to streamline procurement when required.

Recommendation 6: Upon successful testing of this treatment system, Naval Facilities Engineering Command provide other military services and relief organizations with design and procurement information for their use. Use of the Society of American Military Engineers is recommended to provide advanced information on the process on an informal basis.

Refugee support operations in recent years have demonstrated a valid requirement for U.S. military forces to be prepared to assume the lead role in providing temporary shelter until political solutions can be worked out. Engineering forces can extend their effectiveness in these operations with advance preparations to address the inevitable problem of human waste disposal. By taking advantage of prefabrication and existing technologies, the U.S. Navy can lead the way in addressing these pressing environmental issues while there is ample time to prepare.

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Reed, R., October 1994; *Why Pit Latrines Fail: Some Environmental Factors*, Waterlines, Vol 13, No. 2, pp 5-7

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APPENDIX A
SITE VISIT GUIDE

Background:

1. Expected number of displaced persons (male/female):_________/__________
2. Will there be family units?__________ Unaccompanied children?___________
3. Date that first camp required to be complete:__________
4. Expected duration of operation:____________
5. What sort of living conditions are they used to/comfortable with? ______________________

____

____

6. Expected number of residents in each camp: _______________
7. Will there be food preparation facilities in the area requiring food waste disposal? Y N

Site Information:

1. What are the temperature averages and extremes for the area?
   Summer high temp:________ Rainfall average ________
   Winter low temp: ________ Rainfall average ________ Snowfall _________

2. Is the site subject to tropical storms/flooding? Y N

3. What type of soil is found in the area? (Clay, sand, rocky?)____________________________

____

(If possible, consult local excavators/well drillers for information.)

4. Describe the topography. Is the area flat, hilly, rocky? How much and what type of vegetation is present? If possible, obtain a small scale (detailed) topographical map of the site to be used. If not available, sketch major terrain features, especially trees, streams and other bodies of water, and likely stormwater runoff routes. Also include locations of current and future camps. Provide a distance scale on the sketch ____

____

____

____

____

5. Is there drinking water available? Y N
   Distance from site: _______________ Pipe diameter: _______________________
   Operating Pressure: _______________ Gallons per day available: _____________
   How is it treated? (Filtration plant, chlorination...) ______________________________

Are there sources of fresh, untreated water available? Y N

Distance from site: ______________ Source (river, lake...) ______________

Are there sources of salt or brackish water available? Y N
Distance from site: ______________ Source (Ocean, lake...) ______________

Where does the local population get their drinking water? ______________________

____

(If wells are used, consult local residents or well drillers for information on well depth, volume of water that can be extracted, seasonal variations such as wells that dry up in the summer)

6. Is there permanent electrical power available? Y N
   Voltage __________ Amperage _________ Number of phases: 1 2 3
   Frequency (50 cycles or Hertz, 60 cycle...) __________
   Distance from site: __________ How reliable is it? ______________
   Underground or Overhead Cost per kW hour ______________
   Is there temporary electrical power available from portable generators or MUSE units? Y N
   Number and sizes of units______________________________________
   As primary or backup power source? ______________________________

7. Is there a wastewater treatment plant available? Y N
   If so, is there sufficient capacity to discharge into it directly? ______________
   Is there sufficient capacity to receive trucked-in liquid waste from portable chemical toilets? ____
   Where does the plant discharge to? ______________________________
   How does the plant dispose of its solid sludge waste? ____________________

   ____

   Describe the treatment method: Activated Sludge/Trickling Filter/Extended Aeration/ Rotating Biological Contractor/Oxidation Ditch...______________________

8. If no central sewer system is used, how does the local population deal with human waste? (Pit latrines, septic tanks with leach fields, cisterns...) ______________________

____

____

9. Where is the nearest solid waste landfill or dump located? Will it be available for use to dispose of food waste, treatment plant sludge?______________________________

____

Is there a dumping fee? Y N If so, approximately how much? ______________

10. Are there local health problems associated with:
   Contaminated drinking water Y N
   Insect vectors (mosquitos, flies...) Y N
   Animals (mice, rats...) Y N

11. If conditions warrant the installation of a treatment plant, is there a suitable site to locate one in the vicinity? Optimum locations will include the following features:

-Downwind during prevailing winds and distant from local populations and proposed or existing camps (at least 100 yards away).
-At a lower elevation than the camp to allow gravity drainage of waste where possible
-Near a stream or river to allow plant to discharge treated water, but above flood levels
-Near a source of electrical power or provided with generators. If primary power is provided, provision of standby emergency generator is prudent.
-Accessible by road. Road should be capable of carrying dump-truck traffic for sludge disposal and truck delivery of treatment chemicals.

____

____

12. Is there a source of concrete (approximately 75 cubic yards) to construct a surface pad to set a treatment unit on? Y N

13. Are there local firms capable of supplying and operating a package waste treatment plant? Y N ____

14. Are there local firms capable of providing and servicing chemical toilets? Y N __________

____

15. Comments/Points of Contact:____

____

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APPENDIX B
IMHOFF TANK DESIGN CALCULATIONS

The following design calculations are provided for determining the size of an unheated Imhoff tank required to serve a 500 man refugee camp. The design criteria detailed in Table 4 provided the basis for overall design of the Imhoff tank shown in Figure 3. Typical tank external dimension values were selected at the lower range value to compress the tank size. This was done to minimize transportation problems since the tanks will be prefabricated and must be capable of air transport to their sites.

A. Design Criteria:

Table 4. Typical Design Criteria for Unheated Imhoff Tanks (Metcalf & Eddy, 1991).

Design parameter	Unit	Value: Range	Value: Typical
Settling compartment			
Overflow rate peak hour	$gal/ft^2 \cdot d$	600–1,000	800
Detention time	h	2–4	3
Length to width	ratio	2:1–5:1	3:1
Slope of settling compartment	ratio	1.25:1 to 1.75:1	1.5:1
Slot opening	in	6–12	10
Slot overhang	in	6–12	10
Scum baffle			
Below surface	in	10–16	12
Above surface	in	12	12
Freeboard	in	18–24	24
Gas vent area			
Surface area	% of total surface area	15–30	20
Width of opening[a]	in	18–30	24
Digestion section			
Volume (unheated)	Storage capacity		6 months of sludge
Volume[b]	ft^3/capita	2–3.5	2.5
Sludge withdrawal pipe	in	8–12	10
Depth below slot to top of sludge	ft	1–3	2
Tank depth			
Water surface to tank bottom	ft	24–32	30

[a] Minimum width of opening must be 18 in to allow a person to enter for cleaning.
[b] Based on a six-month digestion period.

B. Assumptions

Assumptions made on the quantity and characteristics of waste expected to be generated from a 500 man tent camp were based on design criteria used at U.S. Naval Station Guantanamo Bay, Cuba. The design waste stream includes flows from showers, flush toilets, wash stations and

food preparation facilities.

Table 5. Design Assumptions for Primary and Secondary Treatment

Category	Assumption	Source
Camp Population	500	LANTDIV
Wastewater Volume	40 gal/capita/day 20,000 gal/day	LANTDIV, Metcalf & Eddy
Influent BOD_5	250 mg/l	LANTDIV
Effluent BOD_5	30 mg/l 30 day avg 45 mg/l 45 day avg	LANTDIV
Effluent Total Suspended Solids	30 mg/l 30 day avg 45 mg/l 45 day avg	LANTDIV

C. Design Calculations:

1. Settling Compartment Volume

Flow Volume = (20,000 gal/day) / (24 hr/day) = 833 gal/hr
Minimum detention time = 2 hr
Compartment Volume = 833 gal/hr x 2 hr = 1700 gal = 223 cubic feet

2. Digestion Compartment Volume

Required Volume = 2 cubic feet/capita = 2 cu ft x 500 = 1000 cubic feet

3. Total Volume = 223 cu ft + 1000 cu ft = 1200 cubic feet

4. Tank Dimensions

Minimum depth from water surface to bottom = 24 feet
Tank top surface area = volume / depth = 1200 cu ft / 24 ft = 50 sq ft
Tank length ratio = 2:1 minimum; (2 x width) x (width) = 50 sq ft
Width = 5 ft minimum, use 6 ft
Length = 10 ft minimum, use 12 ft
Height = 24 ft + 1.5 ft minimum freeboard, use 26 ft to allow for sludge sump

5. Check gas vent surface area

   Width = 18 in for cleaning
   Vent surface area = 1.5 ft x 12 ft x 2 = 36 sq ft
   Range is from 15% to 30% of total surface area of 72 sq ft = 11 to 22 sq ft
   Vent surface area is excessive but will not affect tank operation.

6. Check digestion compartment dimensions

   Volume required = 1000 cubic feet
   Outside dimensions = 72 sq feet. Minimum compartment height = 1000 cu ft / 72 sq ft
   Minimum compartment height = 14 ft

7. Check settling compartment dimensions

   Volume required = 223 cubic feet
   Outside dimensions = (6 feet wide - (2 x 1.5 ft gas vents) x 12 ft) = 36 sq ft
   Volume of sloped section at 1.5 to 1 slope= 1/2 base x height x length
   = (.5 x 1.5 ft) x (1.5 x 1.5 ft) x 12 ft x 2 sides
   Volume of triangular section = 40.5 cu ft
   Volume of rectangular section = 223 cu ft - 40.5 cu ft = 183 cu ft
   Depth of rectangular section = 183 cu ft / 72 sq ft = 2.5 ft plus 1.5 ft freeboard = 4 ft

   Total depth of settling compartment from top of tank = 4 ft + 2.25 ft = 6.25 ft

8. Compare internal and external dimensions:

   Internal: Settling compartment height = 6.25 ft
   Digestion compartment = 14 ft
   Total = 20.25 ft
   External: Total tank height = 26 ft

   Sufficient space provided for internal components. Increasing depth of settling compartment to 8 ft to include freeboard, results in digestion compartment volume of 1300 cu ft and a per capita volume of 2.6 cu ft each. Tank dimensions will allow slightly more than 6 months sludge storage before pumping is required.

D. Alternative designs. The above design analysis assumes all waste streams from a camp require full treatment, which is not necessarily true. Installation of individual leach fields for disposal of shower and washwater waste will decrease the flow rate by 50 %, allowing a single tank of the above design to serve two 500 man camps instead of one. Sludge volume, however, will approximately double, requiring sludge to be drawn off at 3 month vice 6 month intervals.

APPENDIX C
RECIRCULATING SAND FILTER DESIGN CALCULATIONS

The following design calculations are provided for determining the size of an recirculating sand filter for treatment of effluent from an unheated Imhoff tank required to serve a 500 man refugee camp. The design criteria detailed in Table 6 provided the basis for overall design.

A. Design Criteria:

Table 6. Typical Design Criteria for Slow Sand Filters (Metcalf & Eddy, 1991).

		Design criteria			
		Intermittent		Recirculating	
Design factor	Unit	Range	Typical	Range	Typical
Pretreatment		Sedimentation (septic tank or equivalent)			
Filter medium					
Material		Washed durable granular material			
Effective size	mm	0.25–0.5	0.35	1.0–5.0	3.0
Uniformity coefficient	UC	<4	3.5	<2.5	2.0
Depth	in	18–36	24	18–36	24
Underdrains					
Bedding					
Type		Washed durable gravel or crushed stone			
Size	in	$\frac{3}{8}-\frac{3}{4}$		$\frac{3}{8}-\frac{3}{4}$	
Underdrain					
Type		Slotted or perforated drain pipe			
Size	in	3–4	4	3–6	4
Slope	%	0–1.0	Flat	0–1.0	Flat
Venting		Upstream			
Pressure distribution					
Pump types		See Table 14-16			
Pipe size[b]	in	1–2	$1\frac{1}{4}$	1–2	$1\frac{1}{4}$
Orifice size	in	$\frac{1}{8}-\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}-\frac{1}{4}$	$\frac{1}{8}$
Head on orifice	ft H_2O	3–5+	5+	3–5+	5+
Lateral spacing	ft	1.5–4	2	1.5–4	2
Orifice spacing	ft	1.5–4	2	1.5–4	2
Design parameters					
Hydraulic loading[c]	gal/ft^2 · d	0.4–1	0.6	3–5	4
Organic loading	lb BOD_5/ft^2 · d	0.0005–0.002	<0.001	0.002–0.008	<0.005
Recirculation ratio		--	--	3:1–5:1	4:1
Dosing frequency	times/d	3–6	4		
Dosing time	min/30 min			1–10	4
Dosing tank volume	days flow	0.5–1.0	0.5	0.5–1.0	0.5
Passes through filter	No.	1	1	2–8	4
Filter medium temperature	°F		>41		>41

[b] Size of distribution pipe depends on the flow rate

[c] Based on estimated flowrate.

B. Assumptions

Assumptions made for effluent quality are provided in Table 5 of Appendix B. Typical values suggested from Table 6 were used for design calculations with the exception of loading rate. The upper range of allowable loading, 5 gallons per square foot per day, was used to compress the filter design.

C. Design Calculations:

1. Filter Area: Area = (Loading) / (Loading Rate) = (20,000 gal/day) / (5 gal/ sq ft-day)
   = 4000 sq ft
   Divide into two filters of 2000 sq ft each

2. Filter Dimensions: Filter dimensions can be tailored to specific site conditions as long as surface area requirements are maintained. For this design analysis, a 2:1 length:width ratio was used resulting in two 32 ft x 64 ft filters.

3. Recirculation Tank Size (Dosing Tank):

   Volume = (0.5) x (1 day flow) = 10,000 gal

4. All other design parameters are as shown in Table 6. Design cross section as shown in Figure 6.

Appendix D
Treatment Decision Flow Chart